RELATIONSHIP OF SAND AND FIBRE IN THE HORNY SPONGE, *PSAMMOCINIA*

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Five species of the genus *Psammocinia* (Irciniidae) are described from Chejudo Island, Namhaedo Island and Wando Island, Korea (*Psammocinia jejuensis, P. mosulpia, P. mammiformis, P. samyangensis* and *P. wandoensis*). *Psammocinia* is characterised by large quantities of sand in spongin fibres, mesohyl matrix and as a thick superficial cortex. In addition to the primary and secondary branching fibres, fine filaments emerge from individual pores in the fibres. Occasionally short secondary fibres are connected to large sand grains, forming bridges between adjacent sand grains. The skeleton formed from sand grains associated with fibres provides additional support for the body of the sponge. ❒ *Porifera, horny sponge, Dictyoceratida, Psammocinia, Korea.*

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Psammocinia (Irciniidae) is characterised in having many sand grains within spongin fibres and the mesohyl matrix, and a surface crust of sand (Bergquist, 1980; Cook & Bergquist, 1996). Lendenfeld (1888, 1889) reported eight species in *Psammocinia*, at that time included as a subgenus of *Hircinia* (*Ircinia*). Of these, only four are currently included in *Psammocinia*: *H. rugosa* Lendenfeld, 1889, *H. arenosa* Lendenfeld, 1888, *H. tenella* Lendenfeld, 1889 and *H. halmiformis* Lendenfeld, 1888, and of these two (*H. rugosa* and *H. tenella*) are synonyms of *P. vesiculifera* (Poléjaeff, 1884) (Hooper and Wiedenmayer, 1994). More recently, Bergquist (1995) reported one new species from New Caledonia, and Cook & Bergquist (1998) described five new species from New Zealand. In Korea, three species of *Psammocinia* were reported from Chejudo Island and Namhaedo Island (Sim, 1998), and two new species, *P. samyangensis* Sim & Lee, 1998 and *P. wandoensis* Sim & Lee, 1998, were described from the South Sea of Korea (Sim & Lee, 1998).

In the present study we examine five species from Korean waters with the aim to determine the extent of skeletal support provided by these foreign skeletal elements, showing that sand is closely associated with the fibres of the sponge, sometimes providing support to the sponge as bridges of primary and secondary fibres connect sand grains in the body.

The principal diagnostic characteristic of Irciniidae is the possession of a third element of the skeleton consisting of fine collagenous filaments beyond the fasciculate primary fibres and uncored secondary fibres (Bergquist, 1980). Filaments of *Psammocinia* emerge from pores in the fibres.

MATERIALS AND METHODS

Specimens of *Psammocinia* were collected from Chejudo Island, Namhaedo Island and Wando Island in Korea; *P. mammiformis* (Manjaedo, Namhaedo Island), *P. mosulpia* (Mosulp'o, Chejudo Island), *P. jejuensis* (Kimnyung, Chejudo Island), *P. samyangensis* (Samyang 1 dong, Chejudo Island) and *P. wandoensis* (Wando Island). Specimens were collected by SCUBA, 10-25m depth, and by fishing-net. For identification of horny sponge, light microscopy and SEM (AKASHI ISI-SS40) were used to determine fibre arrangement.

RESULTS

DISTRIBUTION OF SAND. In all species examined the primary fibres are completely filled with sand grains that form a loosely packed sand core. Secondary fibres may be either partially cored with sand, or lack any sand grains within their cores (Fig. 1D, E). Larger size sand grains are attached to the outside of the fibres (Fig. 2G). Beneath the surface, a sand crust is mixed with foreign spicules (Fig. 1A, B). In one species (*P. jejuensis*) the external surface of the sponge is armoured with pieces of shell debris.

SAND ON THE ECTOSOMAL CRUST. Surfaces of *P. wandoensis, P. mosulpia* and *P. mammiformis* have a sand crust mixed with foreign spicules, whereas *P. samyangensis* has a

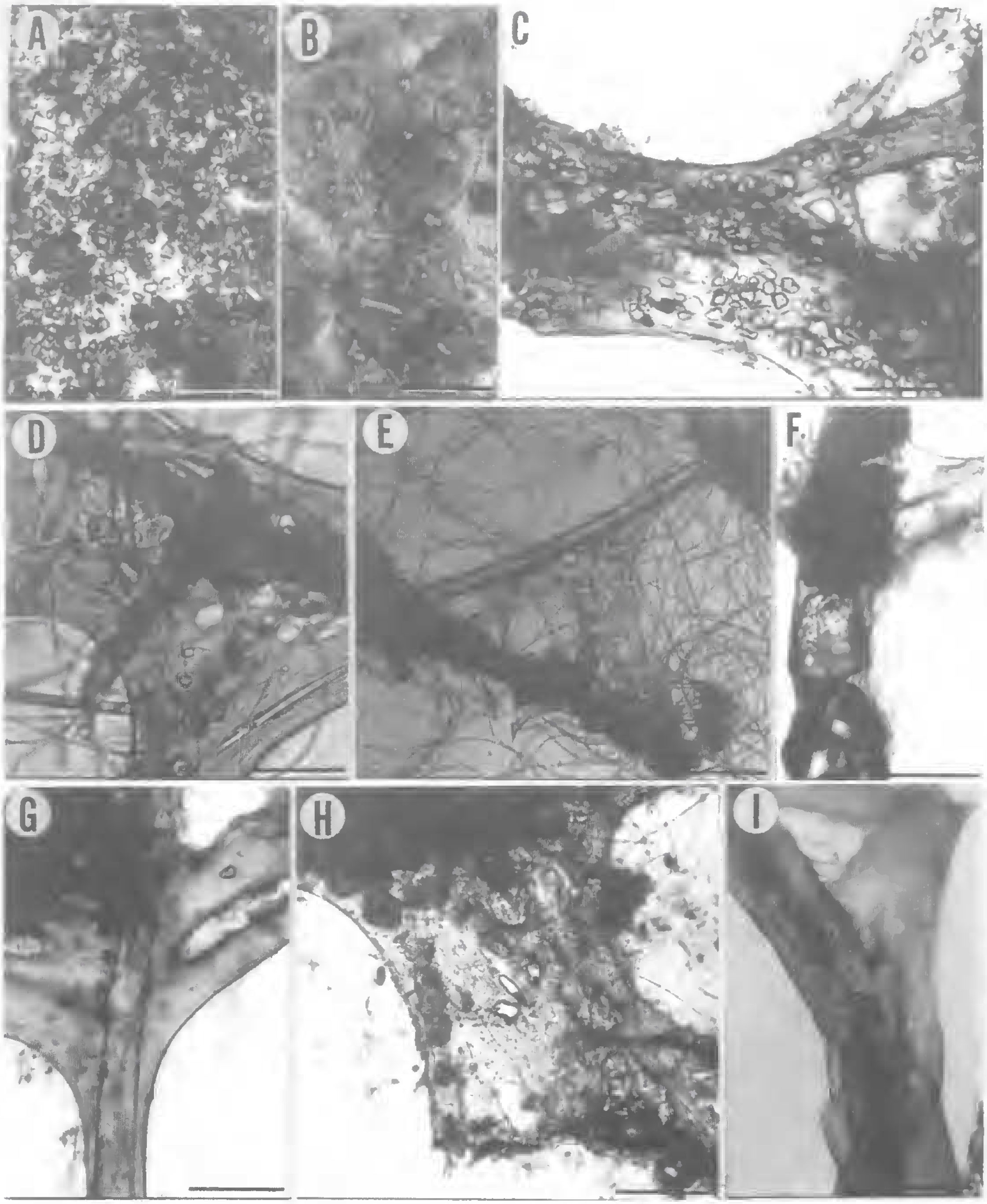

FIG. 1. A-B, *Psammocinia mosulpia*; A, sand crust; B, under-crust mixed with sponge spicules. C, *P. wandoensis*, sand attached inside of fibres. D-E, *P. Samyangensis*; D, primary fibre with sand; E, large oxea supporting fibre. F, *P. mosulpia*, primary fibre with sand. G-H, *P. jejuensis*; G, large oxea in fibre; H, sand in fibre. I, *P. mammiformis*, primary fibre with sand. (Scale bars; A-B, 300μm; C-D, 150μm; E, 300μm; F- I, 150μm)

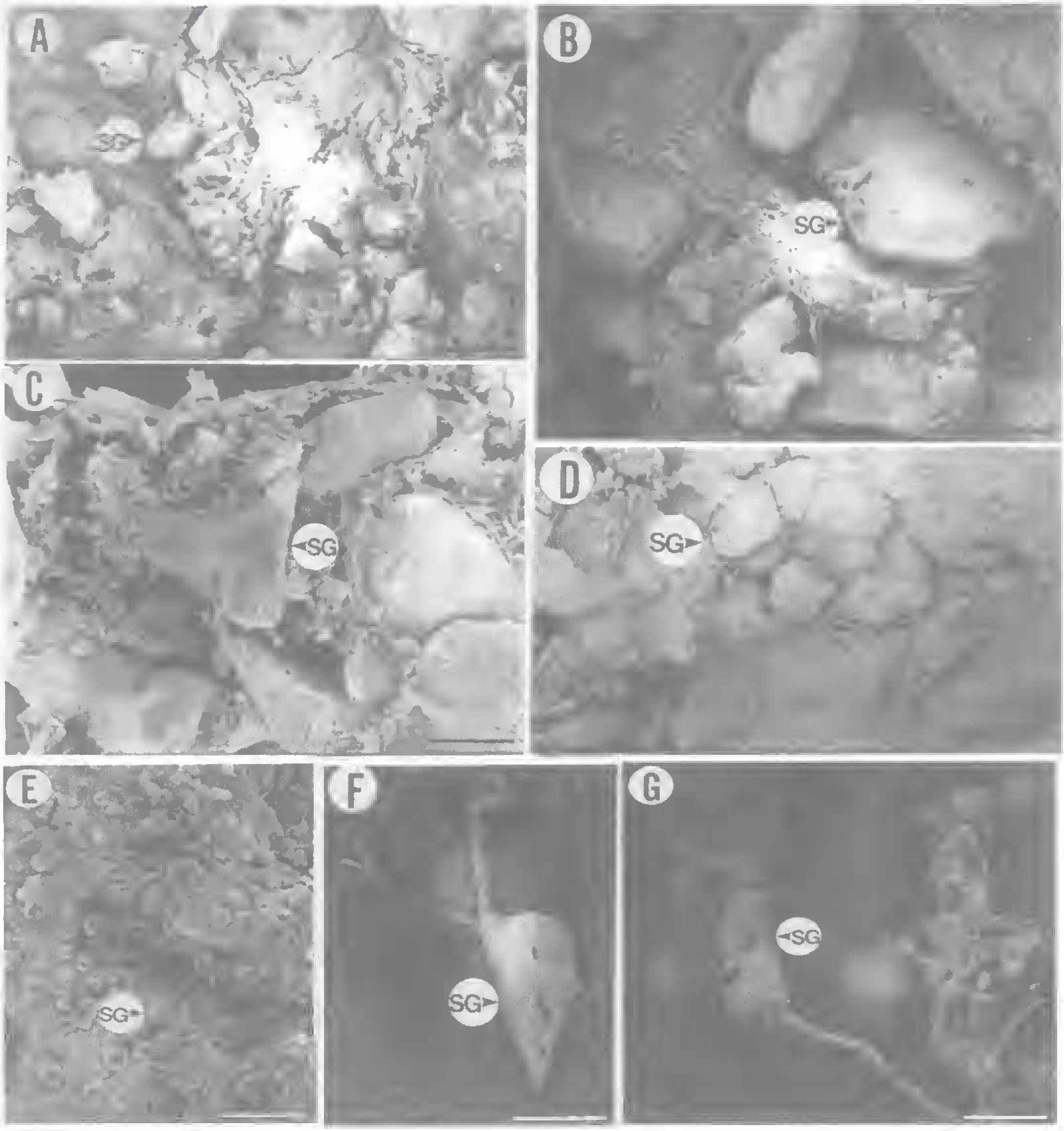

FIG. 2. A, *Psammocinia mammiformis,* choanosome with sand grains (SG). B, *P. samyangensis*, choanosome. C, *P. jejuensis*, choanosome. D, *P. mosulpia*, choanosome. E, *P. wandoensis*, choanosome. F, *P. samyangensis*, choanosome secondary fibre with sand. G, *P. mosulpia*, choanosome fibre with sand (Scale bars: A-D, 400μm; E, 100μm; F, 80μm; G, 300μm).

thin filamentous membrane mixed with large sand grains and pieces of shell, each 1-2.5mm diameter, not strictly a sand crust. The texture of this species is soft and easily torn because the fibre and filament arrangement is very loose. *Psammocinia jejuensis* also has filamentous membrane instead of true sand crust, with large grains of sand and pieces of shell distributed within the surface armour. In *P. mosulpia* there is a black sand crust making this species appear darkly pigmented (Fig. 1A, B).

SAND IN THE MATRIX. The choanosomal matrix also contains many sand grains, with sizes of sand grains varying between each species. In *P. jejuensis* and *P. samyangensis* large sand grains, 0.7-4.0mm diameter, are combined with the filament network (Fig. 2B). In *P. wandoensis* the mesohyl matrix contains smaller size sand grains, 10-70μm diameter (Fig. 2E), whereas *P. mosulpia* and *P. mammiformis* have sand grains of intermediate size, 350-600μm diameter.

SAND IN SPONGIN FIBRES. Sand grains in *P. wandoensis* are attached to the inside of fibres, with grains approximately 50μm diameter and uniformly distributed in a unidirectional plane. In this species the fibres are difficult to differentiate from the closely packed, amalgamated sand grains.

In *P. samyangensis* the accumulation of large sand grains, 10-180μm diameter, completely obscure the axis of primary fibres, and often a single foreign oxea connects adjacent primary fibres like a bridge, further supporting fibres. Rarely, smaller sand is distributed among the primary fibres (Fig. 1D, E).

Psammocinia mosulpia has large sand grains, 100-400μm diameter, contained within transparent fibres which are simple, not fasciculated (Fig. 1F). Sand grains are attached in and outside of fibres.

Psammocinia jejuensis has sand grains within its primary fibres that make up stout fasciculate columns. Sand grains measure 20-220μm diameter. Fibres are easily torn. Secondary fibres may have a large single foreign oxea included, up to approximately 1,440μm long and 80μm wide, appears to support the sponge (Fig. 1G, H). These oxeas are unbroken within fibres.

In *P. mammiformis* there are thick, strong fibres with chain-like, small sand grains included in the centre of fibres (Fig. 1I). Secondary fibres connected to large sand grains, form bridges between adjacent sand grains (Fig. 2F). Sands and fibres are tightly bound together (Fig. 2G).

FILAMENTS AND FIBRES. In all five species of *Psammocinia* we observed that filaments emerge from pores on fibres (Figs 3A-F, 4A-H). These filaments are visible under light microscopy, but are more clearly observed using SEM. In *P. samyangensis* fibre pore sizes vary greatly, apparently correlated to the thickness of filaments emerging. At their base several adjacent filaments fuse to form a central filament (Fig. 3B). At their terminal ends filaments are usually composed of a single terminal knob (Figs 3C, 4H). The fibres seem to be in the form of a branch but we are able to confirm that there is an opening on the end of the branch from which the filament emerges (Figs 3E, F, 4D).

DISCUSSION

In *Psammocina* spongin fibres are thin and either simple or weakly fasciculated. As such, fibres probably do not provide sufficient support for the sponge body. Through the incorporation of sand grains into fibres and at the fibre core, sufficient structural integrity is achieved by these species. In addition to the rigidity received from association with sand grains, fibres of *Psammocinia* are also supported by a large, single oxea in many places within the mesohyl (Fig. 1E). Filaments also serve an important role in the sponge. If the sponge surface lacks a true sand crust, filaments produce a filamentous, cotton-like membrane at the surface. Together these structures provide some measure of skeletal support for the sponge, perhaps compensating for some inadequacy in their own organic skeletal elements.

Bergquist (1995) stated that organic filaments were separated from spongin fibres, whereas we have shown that filaments emerge from the numerous pores throughout the fibre, and thus integral to the sponge fibre system. We also noted that several filaments emerge from a pore on the fibres (Fig. 3A), merge, and continue as a single filament ending in a terminal knob (Fig. 3D, E,

TABLE 1. Main characteristics of the five *Psammocinia* species.

Species	Consistency	Surface	Mesohyl	Fibre and Sand	Filament
P. wandoensis	Very resilient	Thick sand crust	Small sand grains, 10-120μm diameter	Much small sand inside fibres	Filament pores difficult to detect
P. mosulpia	Resilient	Thin sand crust	Medium sand grains, 400-600μm diameter	Sand in and outside of fibre	Filament pores difficult to detect
P. mammiformis	Resilient	Sand crust	Medium sand grains, 350-600μm diameter	Small sand in fibre, chain-like	Filament pores slightly visible
P. jejuensis	Hard but not resilient, easily torn	No sand crust, filamentous membrane	Large sand grains, 700-4,000μm diameter	Much sand in fibre	Filament pores easily visible
P. samyangensis	Very soft, easily torn	No sand crust, filamentous membrane	Large sand grains, 700-4,000μm diameter	Much sand in fibre	Filament pores easily visible

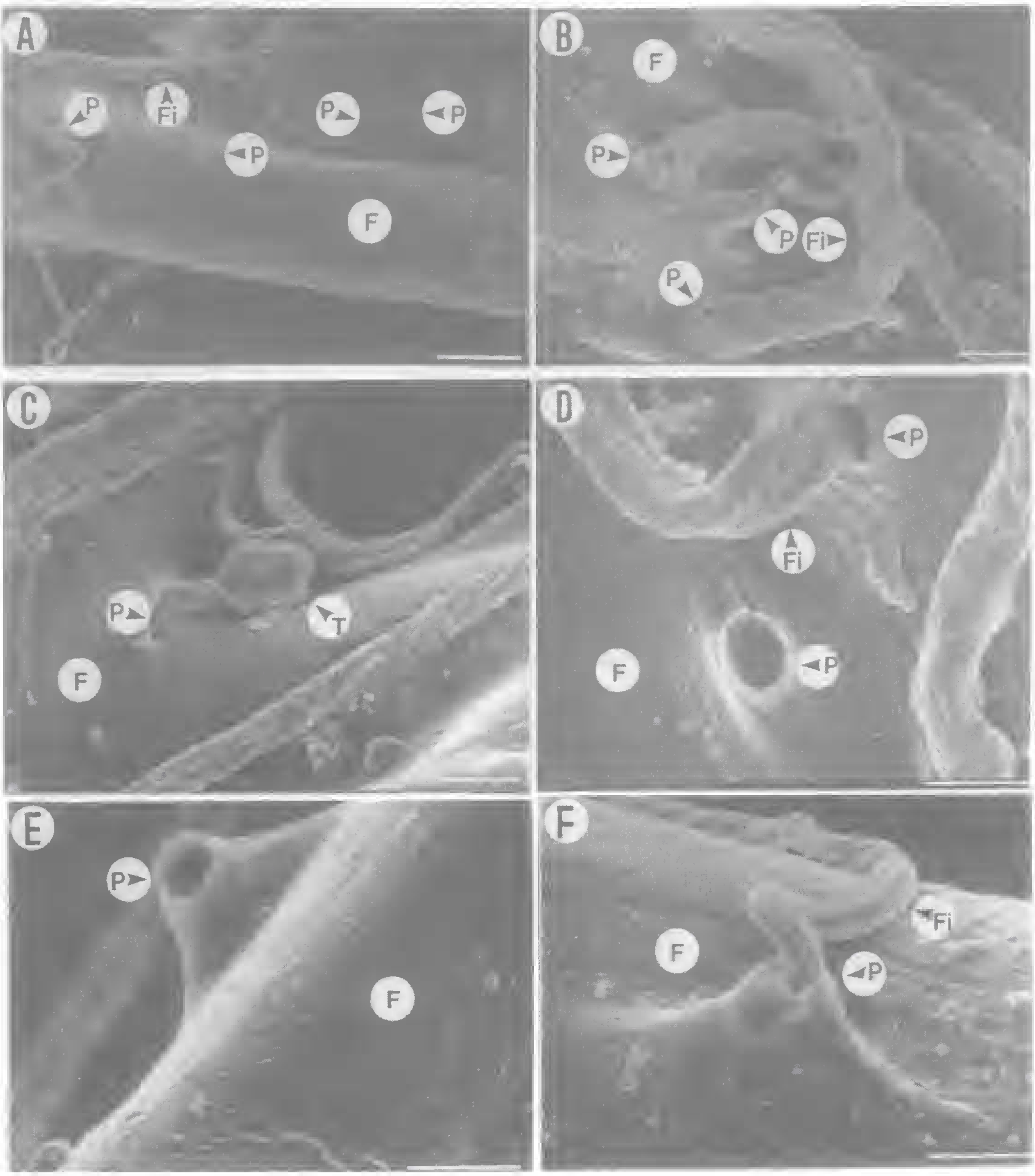

FIG. 3. A-F, *Psammocinia samyangensis*; A, many pores on a fibre (F, fibre; Fi, filament; P, pore); B, base of filaments and pores; C, filament emerging from pore on the fibre (T, terminal knob); D-E, filament and pore on a fibre; F, base of filament and pore (Scale bars: A, 100μm; B-C, 20μm; D-F, 10μm).

H). Very rarely, we noted filaments emerging from both fibre pores and longitudinal slits along the fibres (Fig. 3C), but most commonly filaments appear to emerge only from pores.

Cook & Bergquist (1998) stated that the fibre skeleton in *Psammocinia* is supplemented at fine collagenous filaments, each enlarged terminally at both ends, whereas in the five species examined here these terminal knobs appear at one end only.

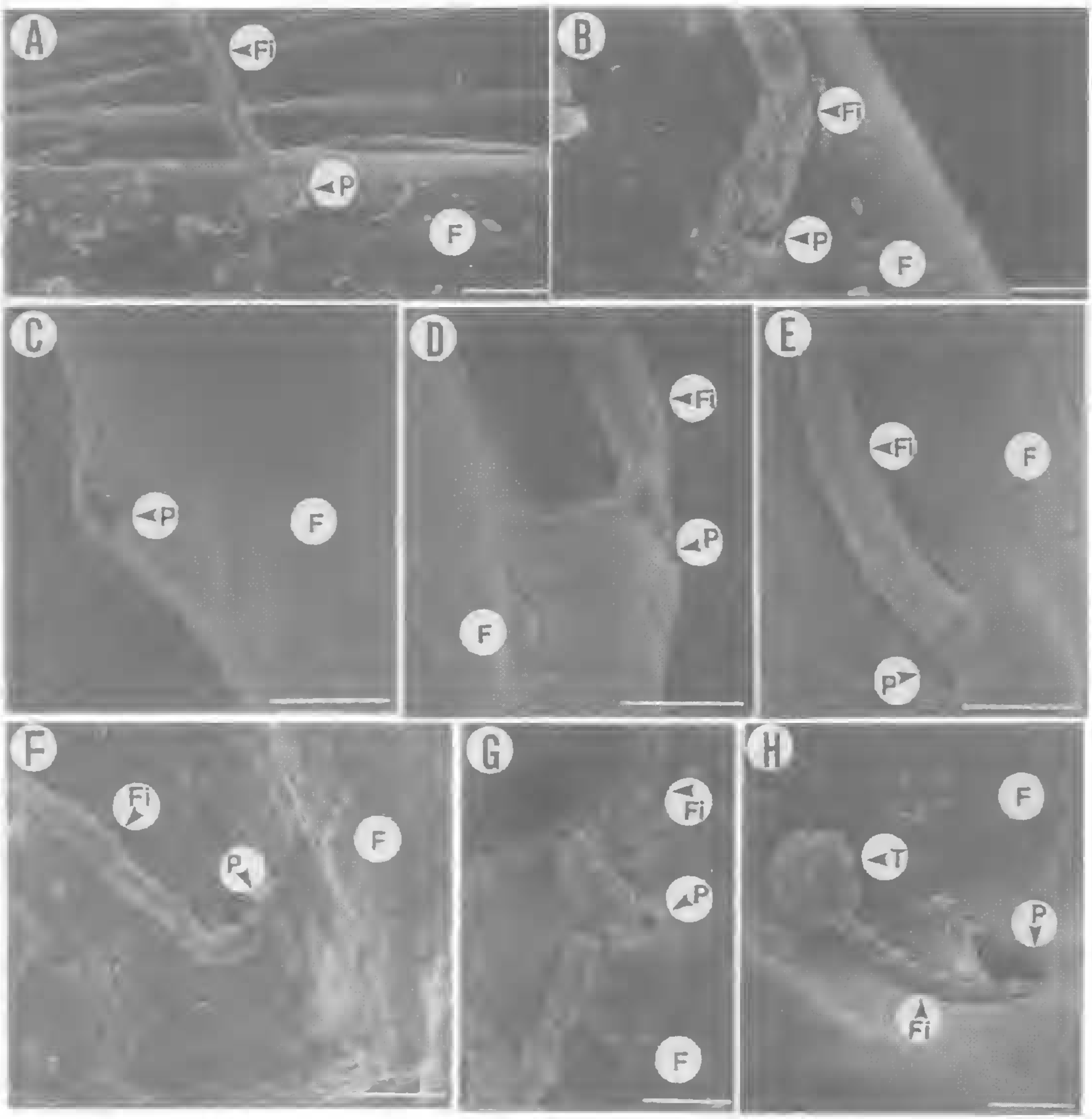

FIG 4. A-B, *Psammocinia jejuensis*, base of filament (F, fibre; Fi, filament; P, pore). C-E, *Psammocinia mammiformis*; filament and pore on a fibre. F, *Psammocinia wandoensis*, base of filament and pore. G-H, *Psammocinia mosulpia*; G, base of filament and pore; H, filament emerging from pore on a fibre (T, terminal knob) (Scale bars: A-B, 20μm; C-E, 10μm; F-H, 20μm).

Several questions still remain regarding the nature of the filaments of *Psammocinia*. One such question concerns the origin and development of the filaments along the fibres, which is a topic for further study. Another question concerns the quantity of filaments in relation to the quantity of fibre pores. In all sponges we examined we observed a large number of filaments, whereas there were far fewer pores from which the filaments emerged, and we assume, with empirical support from SEM studies, that a single pore can produce several filaments over time.

Due to the complex morphology of the fibres and filament arrangement in *Psammocinia*, we were fortunate to observe the multi-based filaments (Fig. 3A) not previously described for this genus. Further studies are required, however, to determine whether this type filament is exclusively a characteristic of *Psammocinia*, or is also found within other sponges of Irciniidae.

As noted in Table 1, all species with a true sand crust are tough and it is difficult to observed filament pores given that so many sand grains are attached to fibre. The two species without a true sand crust are not tough, easily torn, have many filaments and many filament pores were observed.

ACKNOWLEDGEMENTS

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